Space Radiation Analysis Group (SRAG) Concept of Operations for Exploration Missions

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Space Radiation Analysis Group (SRAG)

- Mission: Address the human impacts of space radiation

- Philosophy: As Low as Reasonably Achievable (ALARA)
  - Accomplish mission goals while minimizing radiation dose

- Variety of approaches:
  - Realtime monitoring of particle detectors and dosimeters onboard the vehicle and crew
  - Modelling of the space radiation environment, the vehicle environment, and biological risks due to radiation
  - 24/7 support for Mission Control

- Space radiation sources:
  - Trapped particles in the Van Allen Belts - outbound & inbound
  - Galactic cosmic rays - monitor for long-term health effects
  - Solar Particle Events (SPE) - may result in operational mitigation
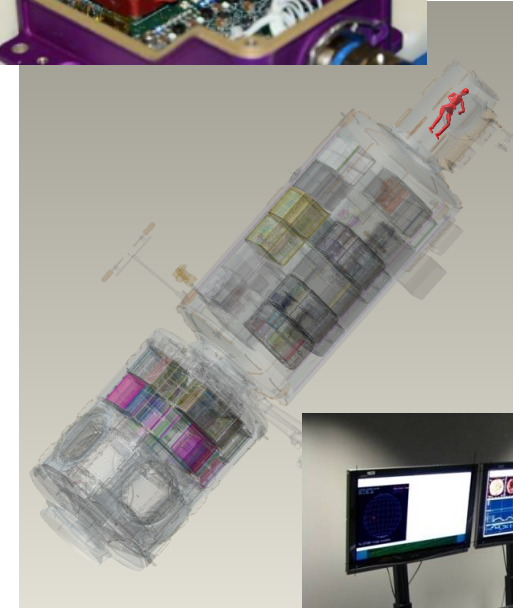
- The geomagnetic cutoff prevents SEP particles from reaching the ISS except close to the geomagnetic poles
  - The geomagnetic field is a 'filter' of ionizing particles
  - Places where the cutoff is low (high latitudes) ionizing solar particles can stream into ISS altitudes
  - Cutoff modulates ground track passes in and out of high latitudes

- Exposures to ISS crew have not been extreme due to significant protection by the geomagnetic field during the most intense SEP time intervals
  - Operationally reduced impact – ~10 min twice per 90 min revolution for ~12h per day (approximately regions inside purple ovals)
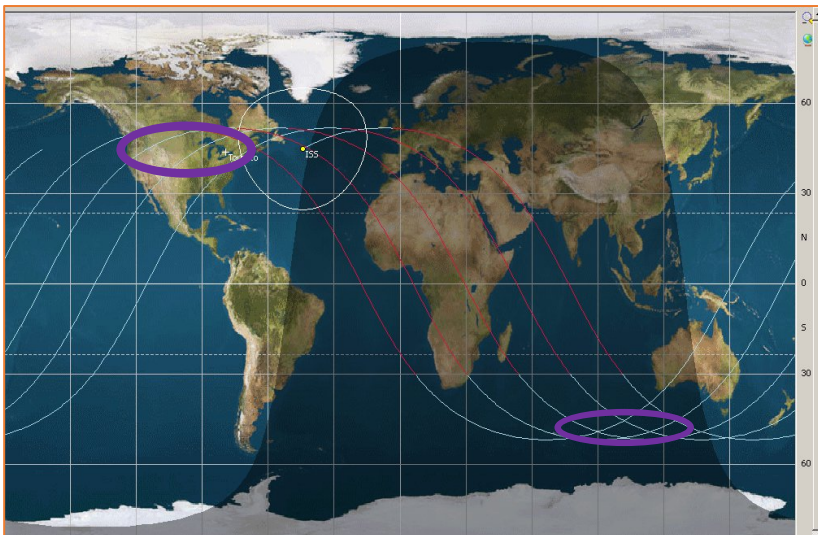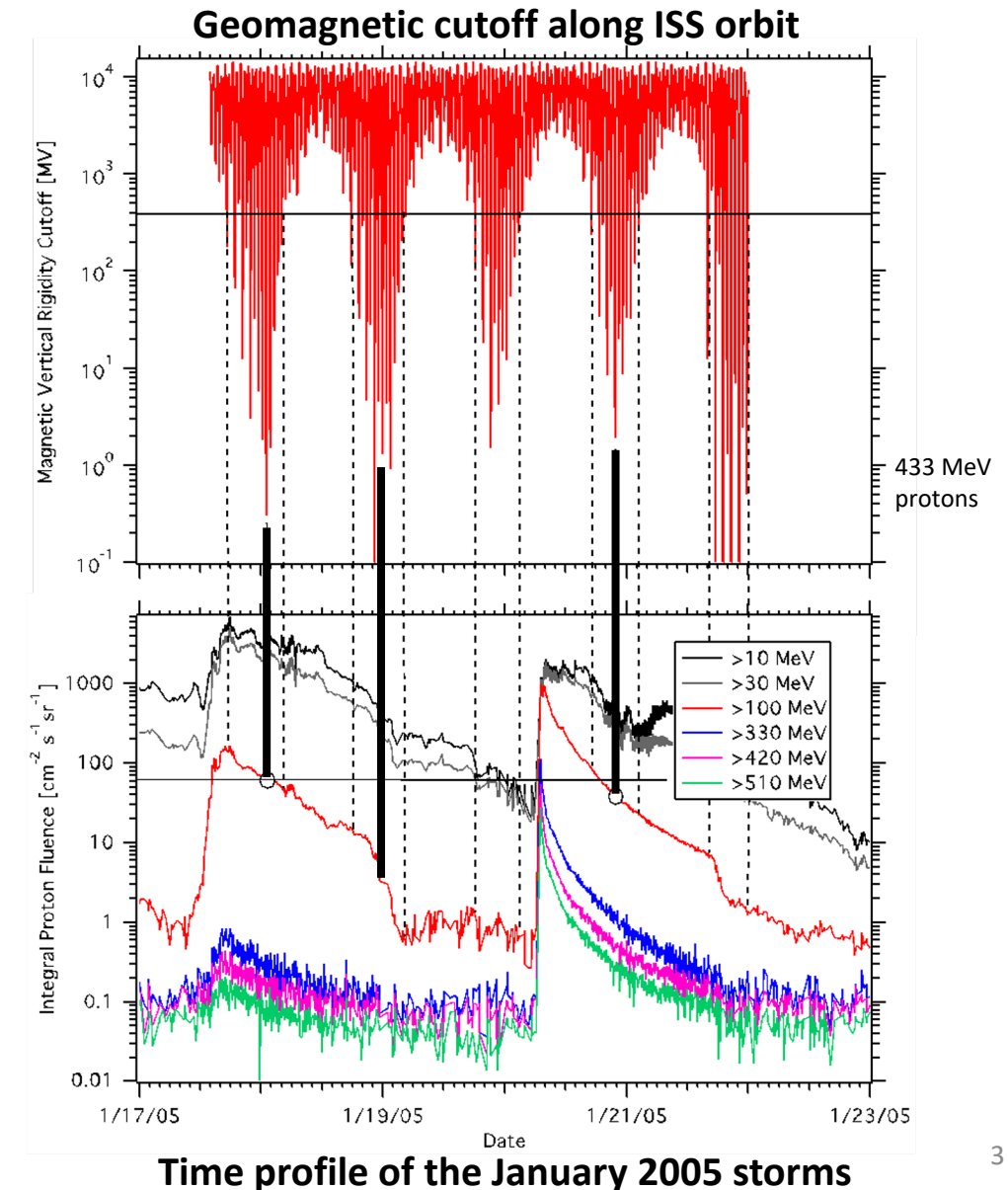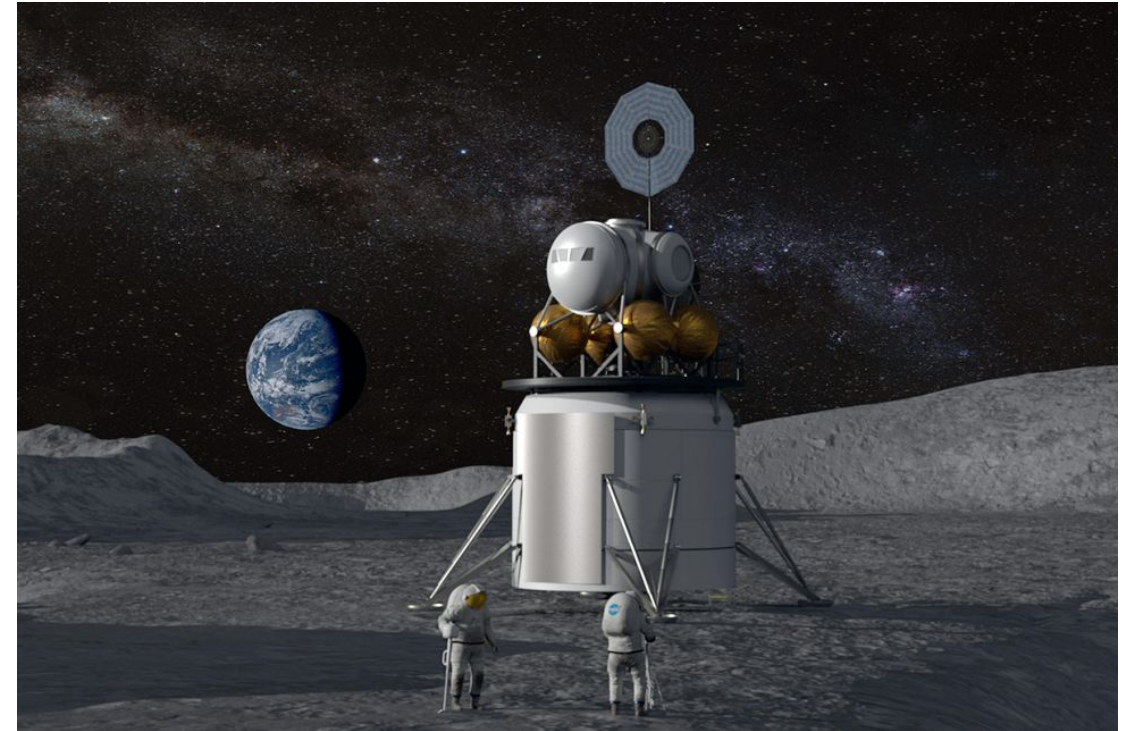
Image credit without circles: Wikipedia

Geomagnetic cutoff along ISS orbit

433 MeV protons

Time profile of the January 2005 storms

3

# SEP Events during Exploration Missions

Missions beyond LEO where crew-vehicle system spends substantial time in 'free-space' the scenario is very different:

Human-vehicle will see full extent of SEP

Image credits: NASA

SPE Environment Assessment Beyond Low-Earth Orbit – Artemis (lunar surface and Gateway)

- Each SPE directed towards the vehicle will impact Artemis
  - SRAG will need more advance warning with detailed assessment of potential outcomes

- **NASA will continue to utilize SWPC for core forecasting for Artemis** and additional operational tools will be utilized for fast response to Mission Control

- SRAG and Community Coordinated Modeling Center (CCMC) at NASA Goddard have collaborated in a joint project called the **Integrated Solar Energetic Proton Event Alert/Warning System (ISEP)** to assemble a suite of SEP models into a real-time framework that includes both US and ESA/EU components.

- ISEP's work includes R2O and O2R efforts to fill modeling gaps and transition models to operations

- The new Moon to Mars (M2M) office at NASA Goddard will provide operational support for the SEP models and the assessment of their products
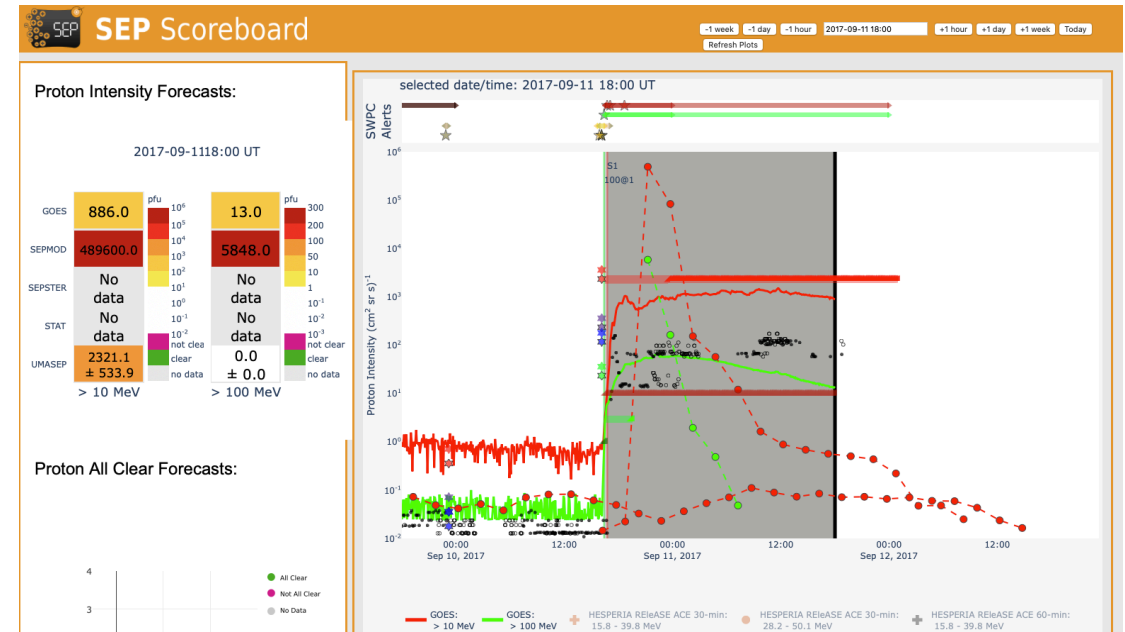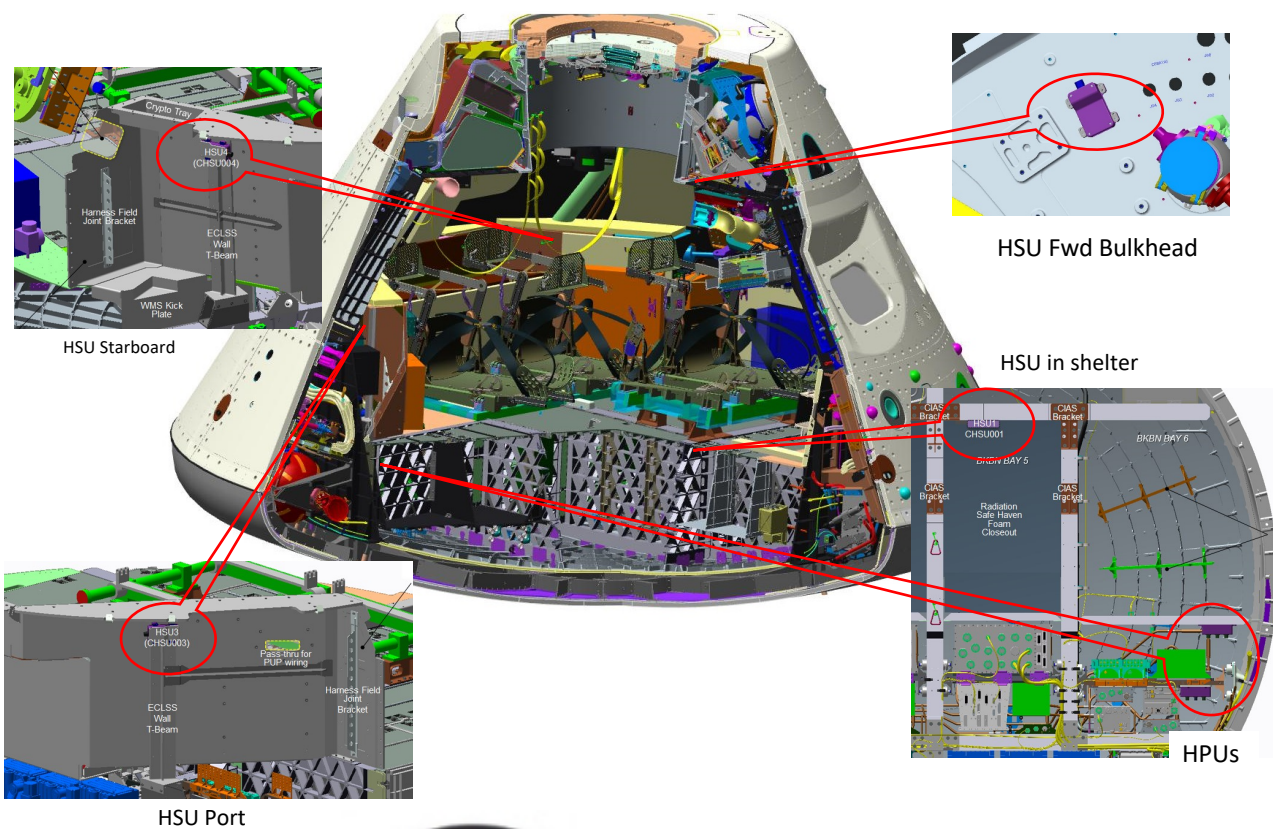

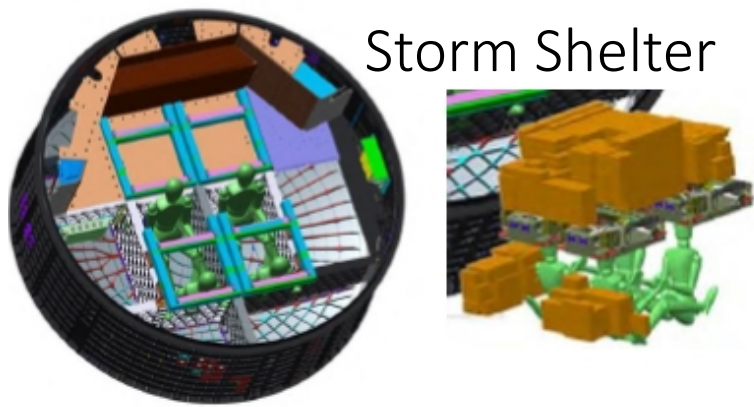CCMC's Intensity SEP Scoreboard is a crucial component of ISEP.

Exploration Concept of Operations

- SRAG has defined a Space Radiation Concept of Operations (ConOps) for Exploration Class missions beyond LEO utilizing the Orion Multi-Purpose Crew Vehicle (MPCV)

- The ConOps outlines the roles and responsibilities of the Radiation console from vehicle launch through vehicle landing
  - EVA operations from both the vehicle and the Lunar surface
  - Operations for the individual mission segments

- Mitigation of radiation hazards is achieved through a multi-pronged approach
  - MPCV designed to maximize overall mission shielding, including the design of a short-term radiation shelter
  - Dosimetry by both passive and active (real-time) vehicle-mounted and personal detectors
  - Satellite assets (GOES, SOHO, ACE, SWFO-L1, etc)
  - 24/7 Console support by SRAG, SWPC, and the Moon to Mars (M2M) office
  - Expanded modeling capabilities: Acute Radiation Risk Tool (ARRT) and ISEP Scoreboards for SPE probability, flux, and dosimetry

Shielding, Real-time Dosimetry, and Shelter

SPE Modeling

HSU Starboard

HSU Fwd Bulkhead

HSU in shelter

HSU Port

HPUs

Storm Shelter

ConOps for Solar Energetic Particle Models during Exploration Missions

SRAG Concept of Operations

Stage	Condition	Observations	Definition	Operator Response	Questions to Answer	Model Type Envisioned
All-clear	Nominal	Magnetograms, Continuum	The term All-clear denotes Nominal conditions where space weather models are forecasting that no ESPE will occur in the next 24 hours and the forecasted probability falls into the Low Concern category.	• Monitor the environment	• Will an event occur or not?	Probabilistic
Watch	Nominal	Magnetograms, Continuum	The term Watch denotes Nominal conditions where space weather models are forecasting that an ESPE is likely to occur in the next 24 hours and the forecasted probability falls into the Medium or High Concern category	• Monitor the environment	• Will an event occur or not?	Probabilistic
Warning	Off-nominal	X-ray flux, coronagraphs, electron flux, proton flux	The term Warning denotes Off-nominal conditions where an enhanced space radiation environment has been observed but does not satisfy the ESPE condition	• Monitor the environment • Inform the FCT • Consider the possibility of an ESPE	• Will an event occur or not? • How intense will the event be? • How long will the event last?	Deterministic
Contingency	Off-nominal	X-ray flux, coronagraphs, electron flux, proton flux	The term Contingency denotes Off-nominal conditions where ESPE conditions are satisfied and actions to crew may be required to minimize the effects	• Monitor the environment • Keep FCT informed • Assess the event • Recommend crew actions	• How intense will the event be? • How long will the event last?	Deterministic

* Low Concern is currently defined as 0-7% probability of event occurrence.

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Response to Solar Energetic Particle Events during Exploration Missions

Scenarios

Scenario	Examples	Crew Response Procedure	Stage Where Action is Taken
IVA	Routine tasks inside the spacecraft	Build shelter within 30 minutes	Warning and Contingency
Critical IVA	Docking, undocking, critical times in trajectory	Task-dependent. Shelter as available	Warning and Contingency
EVA	Spacewalks, lunar surface walks	Return to shelter within 1 hour*	Warning and Contingency
EVA planning	xEMU donning and pre-EVA procedures	Proceed with EVA. Plan to return if an event occurs	All-clear and Watch
		Possibly delay EVA until conditions are clear	Warning and Contingency

*SSP 51073 3.2.6 Emergency Life Support

- Since the response by crew requires only 30-60 minutes, this can all be done in the Warning and Contingency stages. This also reduces the number of false alarms and the need to alter crew tasks

- Current paradigm is that no actions are taken based on the elevated likelihood of an SPE prior to an event occurring

- Special cases such as multiple events in a short time are still being considered. May depend on the exposure from the first event. Mission termination criteria not yet formulated.

Summary

➢ For exploration missions, SPE environment assessments must be improved and expanded

   ➢ Reliable All-clear predictions
   ➢ Detailed accurate advanced warning of SPEs
   ➢ Fast, accurate assessments of SPEs directly following the eruption of a flare or CME

➢ The joint SRAG-CCMC ISEP project is working to address this need and transition models to operations as well as develop the real-time SEP Scoreboards

➢ The new Moon to Mars Office will provide additional operational support to SRAG

➢ A concept of operations for SEP events has been defined for the upcoming Artemis missions